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Estimation of stature from index and ring finger length in a North Indian adolescent population

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ABSTRACT

The identification of commingled mutilated remains is a challenge to forensic experts and hence, a need of studies on estimation of stature from various body parts in different population groups. Such studies can help in narrowing down the pool of possible victim matches in cases of identification from dismembered remains. Studies pertaining to stature estimation among adolescents are limited owing to the ongoing growth process and growth spurt during adolescent period. In view of the limited literature on the estimation of stature in adolescent group, the present preliminary research was taken up to report the correlation between index and ring finger length and stature in a North Indian adolescent population. Three anthropometric measurements; Stature, Index finger length (IFL) and ring finger length (RFL) were taken on the subjects included in the study. Mean stature, IFL and RFL were significantly larger in males than females. Statistically significant correlation was observed between stature, IFL and RFL in right and left hands. Pearson correlation (r) was higher among males than females. Among males and females correlation coefficient was higher for the IFL than the RFL. The present research derives the linear regression models and multiplication factors for estimating stature from IFL and RFL and concludes that the living stature can be predicted from the IFL and RFL with a reasonable accuracy in adolescent population of North India.

1. Introduction

One of the primary aims of any medico-legal investigation is to establish identification, especially in cases involving human remains. The human remains may be in the form of skeletal remains or dismembered and mutilated body parts. Such partially destroyed dead bodies and human remains are frequently encountered in air crashes, intentional mutilation and dismemberment, explosions, and other mass disasters.[1] During the examination of dismembered and skeletal remains, the main aim of the investigation is to estimate age, sex, stature and ancestry of the remains and develop the biological profile. Biological profile, thus derived is a circumstantial identification that helps in narrowing down the pool of possible matching profiles.[2]

Stature estimation from skeletal remains and body parts is based on the principle that height of an individual has a definite and linear relationship with various body parts and long bones of an individual. Various studies in the past have established that stature can be reconstructed from various body parts and individual bones with reasonable accuracy. Earlier studies have utilized skull and cephalo-facial anthropometry,[3–10] long bones and their fragments,[11–22] scapula and hip bones,[23–25] and small bones of hand and foot[26–28] for estimation of stature. It has been shown that the estimation of stature is more accurate and reliable using long bones than any other part of the body. Anthropometric studies for estimation of stature from upper and lower extremities, and hands and feet in forensic examinations have been conducted.[29–41] Studies on the estimation of stature from finger length and phalanges are however, limited in literature. Extensive literature review with 'finger lengths', 'phalanges' and 'stature' as keywords revealed only a few studies on the subject. Rastogi et al.[42] estimated stature from middle finger length in a study conducted on right handed individuals from North and South India. The study reports a positive correlation between middle finger length and stature. Habib and Kamal[43] carried out a study of correlation of stature with measurements of hand and phalange lengths in an Egyptian population. They observed that hand length gives better prediction of stature than the length of phalanges and further concluded that the estimation of stature is more reliable in Egyptian females than males. Jasuja and Singh[44] in their study on hand and phalange

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lengths among North Indians found a positive correlation of various measurements of hand and phalange lengths with stature of an individual. They studied Jat Sikh population of Punjab in North India and calculated regression equations for estimation of stature from prints as well as actual measurements of hand and phalange lengths. These studies on stature estimation from different measurements of hand however, were conducted on adult populations.

In modern forensic casework, there is a need of studies that can help in estimating stature of a person from various body parts to establish the biological profile of an unidentified individual especially in cases of homicide and murder; where the body may be dismembered into various pieces to conceal the identity of the victim and to mislead the investigating agencies. Any investigation that aims to develop standards that help in establishing the biological profile may be deemed valuable in forensic context as there is always a potential for identification of a missing person based on these studies. Paucity of literature on stature estimation in adolescent population and on estimation of stature from index finger length and ring finger length, has prompted the authors' to take up the present preliminary research. The objective of the present research is to study the correlation between index and ring finger length and stature in a North Indian adolescent population. The study derives the linear regression models and multiplication factors for estimation of stature from index finger length and ring finger length. The investigation further explores the predictive accuracy of regression models derived for reconstruction of stature from index and ring finger lengths in adolescents from North India.

2. Materials and methods

2.1. Subjects

The subjects included in the present study belong to Rajput caste – a major endogamous group in the state of Himachal Pradesh in North India. The study is based on a randomly selected sample of 140 subjects (70 males and 70 females) from Government Senior Secondary School, Naggar and Government High School, Nathan. The subjects were aged between 14 and 18 years. Mean age was 16.0 ± 1.3 years in males and 15.5 ± 1.0 year in females. The adolescent age group was chosen in wake of increasing crime against teenagers, and paucity of literature on stature estimation in adolescent populations.

2.2. Anthropometric measurements and techniques

Three anthropometric measurements; Stature, index finger length (IFL) and ring finger length (RFL) were taken on the subjects using standard procedures and landmarks following Vallois[45] and Manning et al.[46] The finger measurements were taken independently on left and right sides of the subjects. Handedness has been associated with bilateral differences in hand dimensions. Since the study deals with estimation of stature from finger lengths, handedness and resultant asymmetry may affect the regression models derived for stature estimation. Hence, only right handed subjects were included in the study. All the measurements were taken in a well-lit room using standard anthropometer and sliding calipers (Galaxy Informatics India, New Delhi) in centimeters to the nearest millimeter. Subjects with any disease or deformity of fingers or spine were not included in the study.

2.2.1. Technique for measuring stature

Stature is the vertical distance between the point vertex and the floor. The subjects were made to stand in an erect posture against a wall without any wear on head and foot. The feet axis was parallel or slightly divergent and head was in Frankfort Horizontal plane when the measurement was taken using the anthropometer. The anthropometer was held vertically in front of the subject exactly in mid-sagittal plane and by the right hand, movement of cross rod was controlled. No pressure was exerted since this is a contact measurement.

2.2.2. Technique for measuring index finger length (IFL)

Index finger length was measured from the mid point of the proximal crease at the base of the index finger to the tip of the index finger using sliding calipers.

2.2.3. Technique for measuring ring finger length (RFL)

Ring finger length was measured from the mid point of the proximal crease at the base of the ring finger to the tip of the ring finger using sliding calipers.

2.3. Technical/measurement error

While collecting the data, the instruments were regularly checked for their accuracy. All the measurements were taken by a trained physical anthropologist (N Asha). Before taking up the present research, finger lengths (IFL, RFL) and stature was measured thrice in 15 subjects and the technical error was calculated following Schell et al.[47] The measurement error is defined as the square root of the sum of the squared deviations divided by twice the sample size ($S^2 = \sqrt{\sum d^2/2n}$). The same formula was applied to the left–right differences. The value of '*F*' statistics (*F*-ratio) was calculated. Table 1 presents the sizes of the technical error variance in the finger lengths. The technical error within side and between sides is described as the 'S^2 within side' and 'S^2 between side' and the ratio of the two errors is distributed as an *F*-statistics. *F*-ratio, for all the measurements is statistically significant at the α-level of $P < 0.01$. Hence, the variation due to sides is several times larger than the measurement error, indicating that measurement error contributes but little to the difference between sides. The results indicate that the technical error contributes negligible to the measurements and the measurements are reproducible without significant technical error.

Table 1
Technical error of measurement within and between sides of finger lengths.

Finger length	S^2 within side	S^2 between sides	*F*-ratio
IFL	0.0342	0.3216	9.4035[a]
RFL	0.0463	0.3123	6.7451[a]

IFL – Index finger length, RFL – Ring finger length.
[a] *P*-value < 0.01.

2.4. Statistical analysis

The data was analyzed using SPSS, version 11.0, statistical analyses programme (SPSS Inc., Chicago, IL, USA). Sex differences in

Table 2
Descriptive statistics of stature and finger length (cm).

	Male ($n = 70$)		Female ($n = 70$)	
	Range	Mean (S.D.)	Range	Mean (S.D.)
Stature	137.2–178.5	161.65[a] (8.09)	139.9–166.4	153.13[a] (5.11)
RIFL	5.6–8.2	6.95[a] (0.48)	5.8–7.5	6.53[a] (0.39)
RRFL	5.8–8.3	7.23[a] (0.47)	5.9–7.9	6.73[a] (0.41)
LIFL	5.5–8.2	6.97[a] (0.47)	5.8–7.6	6.55[a] (0.40)
LRFL	5.8–8.4	7.26[a] (0.48)	5.9–7.9	6.73[a] (0.41)

RIFL – Right Index Finger Length, RRFL – Right Ring Finger Length, LIFL – Left Index Finger Length, LRFL – Left Ring Finger Length, S.D. – Standard Deviation.
[a] *P*-value < 0.001.

Table 3
Pearson correlation (r) between finger length and stature (cm).

Stature	Males ($n = 70$)	Females ($n = 70$)
RIFL	0.714[a]	0.531[a]
RRFL	0.671[a]	0.453[a]
LIFL	0.748[a]	0.489[a]
LRFL	0.674[a]	0.367[a]

RIFL – Right Index Finger Length, RRFL – Right Ring Finger Length, LIFL – Left Index Finger Length, LRFL – Left Ring Finger Length.
[a] P-value < 0.001.

the stature, index finger length and ring finger length was tested using students t-test. Pearson's correlation coefficient was calculated and the correlation between the stature and index and ring finger length was drawn. Linear regression models and multiplication factors were derived for stature estimation. A multiplication factor was derived by dividing stature by index and ring finger length in each individual. Mean of multiplication factor thus derived was taken as the multiplication factor for the estimation of stature from index and ring finger length in right and left hand. Regression formulae were derived for stature estimation from index finger length and ring finger length in males and females, keeping stature as the dependent variable and IFL and RFL as an independent variable. P-value of less than 0.05 was considered as significant.

3. Results

The stature ranged from 137.2 cm to 178.5 cm in males and from 139.9 cm to 166.4 cm in females. Mean stature was significantly larger in males (P-value < 0.001). Mean IFL on right and left sides respectively was 6.95 cm and 6.97 cm in males and 6.53 cm and 6.55 cm in females. RFL was larger than IFL in males and females and the mean RFL on right and left sides respectively was 7.23 cm and 7.26 cm in males and 6.73 cm each in females. Finger length measurements (IFL, RFL) were significantly larger in males than females (P-value < 0.001) in both hands. Descriptive statistics of stature, IFL and RFL in both hands are shown in Table 2. Statistically significant correlation was observed between stature and finger lengths (IFL, RFL) in right and left hands (Table 3). Pearson correlation (r) for stature and finger lengths was higher among males (ranging between 0.671 for the right RFL and 0.748 for the left IFL) than females (ranging between 0.367 for the left RFL and 0.531 for the right IFL). Among males and females, correlation coefficient was

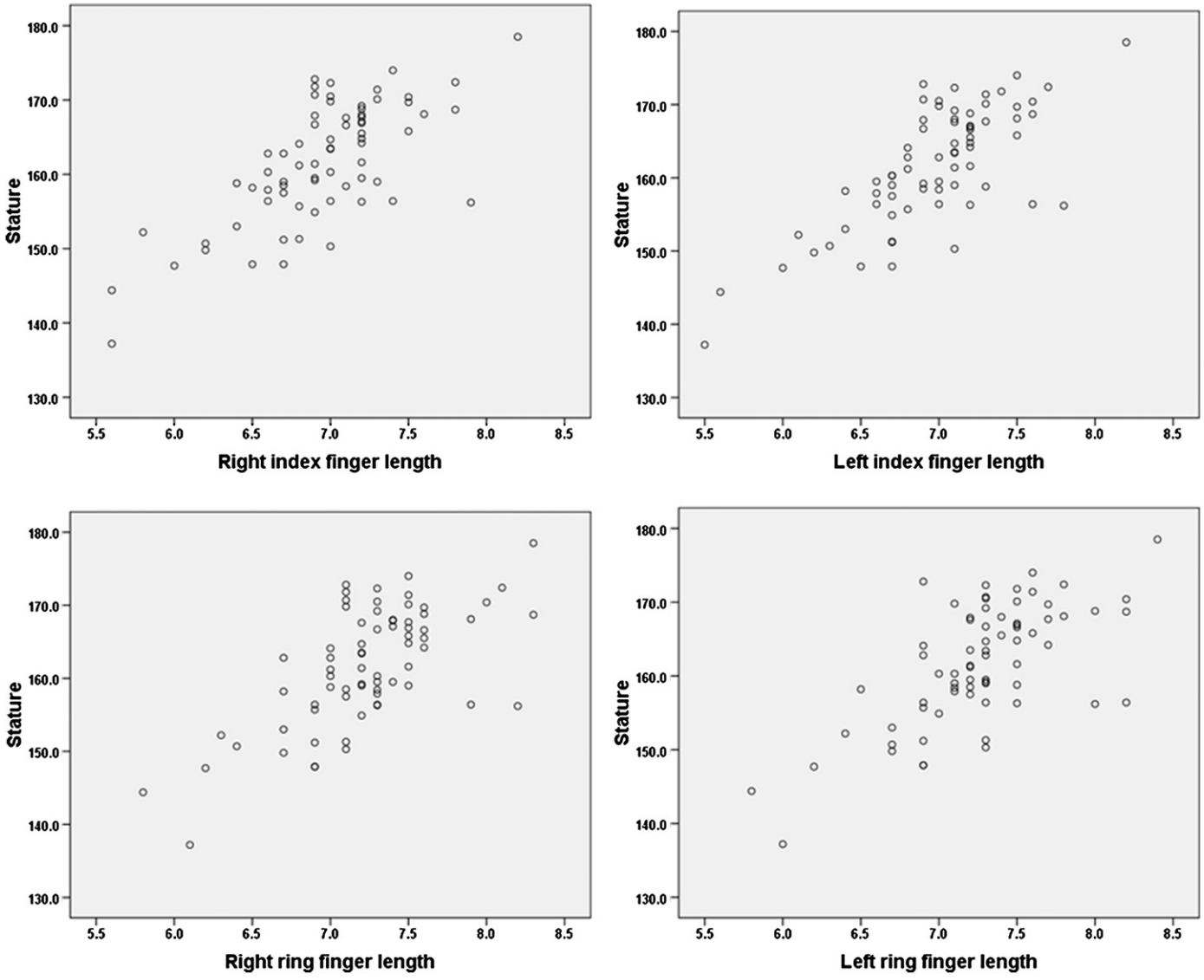

Fig. 1. Relationship between index and ring finger length (cm) and stature (cm) among males.

higher for the index finger length than the ring finger length. The relationship between IFL and RFL, and stature among males and females is shown in Figs. 1 and 2 respectively (P-value < 0.001).

Multiplication factors and linear regression models were determined for estimation of stature. The multiplication factors derived for the estimation of stature from IFL and RFL in both hands are shown in Table 4. Linear regression models derived for reconstruction of stature in males and females are shown in Table 5. IFL and RFL showed a significant correlation with the stature in males and females (P-value < 0.001). Coefficient of determination (R^2) and Standard Error of Estimate (S.E.E) was determined to find the predictive accuracy of linear regression models for stature estimation from IFL and RFL. The S.E.E in stature estimation using linear regression models ranged between 4.37 cm and 4.79 cm among females and between 5.41 cm and 6.04 cm in males. Left IFL in males and right IFL in females appear to be the better predictors of stature (Table 6).

4. Discussion

The results of the present study show that the stature is significantly higher in males than in females. Index finger and ring finger lengths were found to be significantly larger in male than female adolescents included in the study. Earlier studies conducted on hand dimensions in different adult populations report larger hand dimensions in males than females. Agnihotri et al.[34] in a Mauritian population, Rastogi et al[37] and Kanchan and Rastogi[48] in adult North and South Indian population, Sanli et al.[49] in a Turkish population, Krishan and Sharma,[31] Kanchan et al[50] and Krishan et al.[51] in a North Indian population reported larger hand length and hand breadth in males than females. Kanchan et al.[52] reported a larger index and ring finger lengths in males in an adult South Indian population. Another study by Kanchan et al.[53] on South Indian adolescents, reported a significantly larger ring finger length in males. The index finger length however, did not show any statistically significant sex differences in the study. The study of Kanchan and Kumar[54] on South Indian children did not find any statistically significant sex differences in index and ring finger lengths between males and females. The statistically significant sex differences in male and female dimensions have been attributed to the early skeletal maturity in girls than boys; consequently, the boys have around two more years of physical growth.[31] In addition to this, cultural factors such as differential upbringing of the two sexes may have effect on growth and development. This

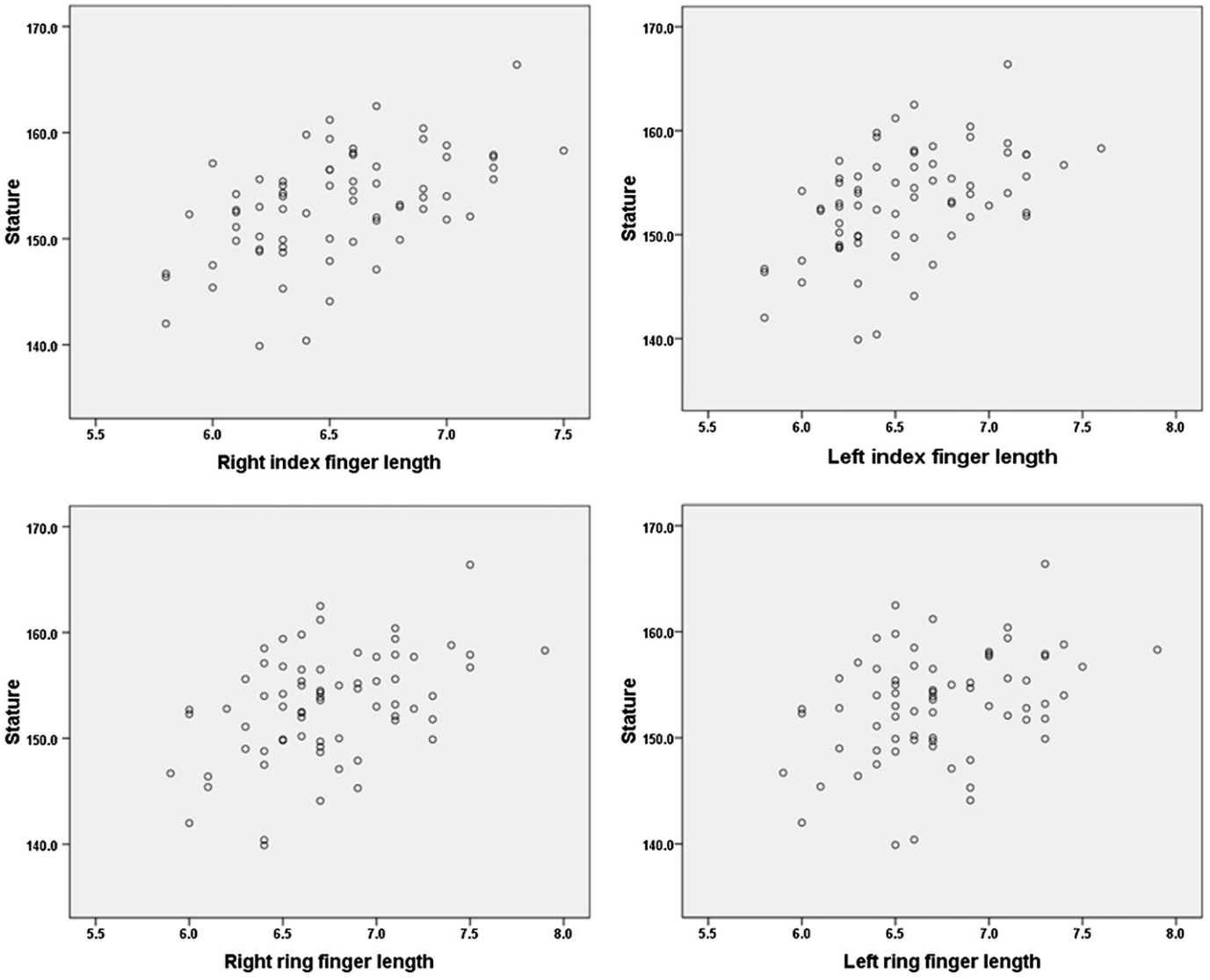

Fig. 2. Relationship between index and ring finger length (cm) and stature (cm) among females.

Table 4
Multiplication factors derived for stature estimation from index and ring finger length (cm).

	MF-male ($n = 70$)		MF-female ($n = 70$)	
	Range	Mean	Range	Mean
RIFL	19.77–26.24	23.32	21.11–26.18	23.52
RRFL	19.05–24.90	22.39	20.04–25.45	22.81
LIFL	20.03–25.79	23.24	20.83–25.70	23.44
LRFL	19.07–25.04	22.31	20.04–25.45	22.81

MF– Multiplication Factor, RIFL – Right Index Finger Length, RRFL – Right Ring Finger Length, LIFL – Left Index Finger Length, LRFL – Left Ring Finger Length.

may include differences in amount, time and quality of food, exercise, ability to move freely as well as psychological well-being. These along with other enculturative practices are often discriminatory toward girls in developing countries. It causes nutritional and psychological stress on the individuals which further hampers physical growth of females. Coupled with these factors is the fact that there is low birth spacing among many families in developing countries especially in the area under study. The boys may get more time to develop and mature than girls owing to the social and community pressures on the parents for a male offspring.

In the present study, the IFL and RFL are found to be significantly correlated with stature. Among studies done in adult populations, Rastogi et al.[42] have examined the relationship of middle finger length with stature and found a positive correlation between stature and middle finger length. Habib and Kamal[43] and Jasuja and Singh[44] in their studies on reconstruction of stature with measurements of hand and phalange lengths have reported a similar observation. With regard to the positive and linear relationship between stature and two finger lengths reported in the present study, the Pearson correlation coefficient (r) between stature and finger lengths ranges between 0.671 and 0.748 in males and between 0.367 and 0.531 in females. The maximum correlation coefficient was observed in the right ($r = 0.714$) and left index finger length ($r = 0.748$) in males. The correlation values obtained in the present study are compared with correlation values obtained for different body parts in earlier studies in adult population from the region. The aim of this comparison is to see if the degree of correlation between stature and finger length in adolescent population is similar to that obtained for other body parts in adult populations from the region. These correlation values observed in the present research are comparable to those reported in adult North Indian populations by Krishan and Sharma[31] on correlation between stature and hand length ($r = 0.686$ on the right side), and stature and foot length ($r = 0.741$ on the left side) and in another study by Krishan[7] on relationship of stature with maximum head length ($r = 0.775$) and horizontal circumference of head ($r = 0.781$). Therefore, it may be suggested that the index and ring finger length in adolescents have a similar relationship with stature as obtained in cases of hand length, foot length, head length and horizontal circumference of head in adult Indian populations. From the regression models derived for stature estimation in the study, it is observed that the standard error of estimate in the predicted

Table 5
Linear regression models derived for reconstruction of stature from index and ring finger length (cm).

	Males ($n = 70$)	Females ($n = 70$)
RIFL	77.862 + 12.061 (RIFL[a])	107.961 + 6.921 (RIFL[a])
LIFL	71.403 + 12.948 (LIFL[a])	112.536 + 6.198 (LIFL[a])
RRFL	77.305 + 11.661 (RRFL[a])	114.928 + 5.676 (RRFL[a])
LRFL	78.280 + 11.481 (LRFL[a])	122.437 + 4.559 (LRFL[a])

RIFL – Right Index Finger Length, RRFL – Right Ring Finger Length, LIFL – Left Index Finger Length, LRFL – Left Ring Finger Length.
[a] P-value < 0.001.

Table 6
Predictive accuracy for regression models derived for reconstruction of stature from index and ring finger lengths.

	Males ($n = 70$)		Females ($n = 70$)	
	R^2	S.E.E (cm)	R^2	S.E.E (cm)
RIFL	0.509	5.71	0.281	4.37
LIFL	0.560	5.41	0.239	4.49
RRFL	0.451	6.04	0.205	4.59
LRFL	0.454	6.03	0.367	4.79

RIFL – Right Index Finger Length, RRFL – Right Ring Finger Length, LIFL – Left Index Finger Length, LRFL – Left Ring Finger Length, R^2 – Coefficient of Determination, S.E.E – Standard Error of Estimate.

stature in the present study was more in case of males than females. The observation suggests that the accuracy of stature estimation in females is more than that of males. Similar findings were reported by Krishan and Sharma,[31] Habib and Kamal[43] and Jasuja and Singh[44] in their earlier studies. However, owing to the lack of studies on stature estimation in adolescent population and on stature estimation from index finger length and ring finger length in literature, the findings of our study cannot be compared per se.

The results of the present research indicate that statistically significant relationship exists between stature and the finger lengths (IFL, RFL) in adolescents. The present preliminary study shows that the living stature can be predicted from the index and ring finger lengths with a reasonable accuracy. Studies pertaining to stature estimation among adolescents are limited owing to the ongoing growth process and growth spurt during adolescent period. When children and adolescents are the victims of crime or disasters, estimation of age remains the prime criterion in process of identification. In such cases, once the age of the deceased is established, regression models derived for estimation of stature can be applied to establish the biological profile of the victim. In view of the fact that the identification of commingled mutilated remains is a challenge to forensic experts, new methods for estimating stature from various body parts must continue to be developed and tested. A word of caution though; the linear relationship of the stature with body parts of the individual is not stable during the adolescent age group hence, the regression models derived for adolescent group in the study should not be applied to adult populations. Future studies on stature estimation among adolescents are proposed so that the amount of variation and accuracy of the stature estimation formulae can be better known among adolescent age groups. Further research on the subject, particularly on different populations throughout the world, will continue to provide valuable information for forensic anthropologists to aid in reconstructing the stature.

Conflict of interest

The authors declare that there is no conflict regarding this research and the manuscript.

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Ethical approval

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